Tire Treadwear Products and 6PPD-Quinone

A Primer for Public Health Laboratories

Environmental and public health laboratories play a critical role in monitoring contaminants of emerging concern that may affect environmental quality and human health. This primer provides an overview of tire treadwear products (TTPs), with a focus on 6PPD-quinone (6PPDQ), current analytical methods and key laboratory considerations.

About Tire Treadwear Products

TTPs are a complex mixture that includes tire wear particles (TWPs), tire and road wear particles (TRWPs; tire-derived particles mixed with road material) and associated chemical additives and transformation products. Modern tires contain numerous additives, including the antioxidant 6PPD (N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine), which prevents rubber degradation (**Figure 1**).

In addition to tires, 6PPD may also be present in other rubber-containing products, such as footwear, synthetic turf infill and synthetic playground surfaces. When released into the environment, 6PPD can react with ozone to form 6PPDQ, a transformation product associated with this mixture and now recognized as highly toxic to certain aquatic species.

While TTPs encompass a broad range of tire-derived particles and associated chemicals, most current toxicological research, environmental monitoring and analytical method development is focused on 6PPDQ due to its demonstrated aquatic toxicity.

Key environmental characteristics of TTPs and 6PPDQ:

- Generated through tire wear and deposited on roadways as TRWPs
- Mobilized into waterways during precipitation and stormwater runoff events
- Detected in stormwater, surface water, sediment, dust, air and biota
- 6PPDQ has been measured in water at low nanogram per liter (ng/L) concentrations.

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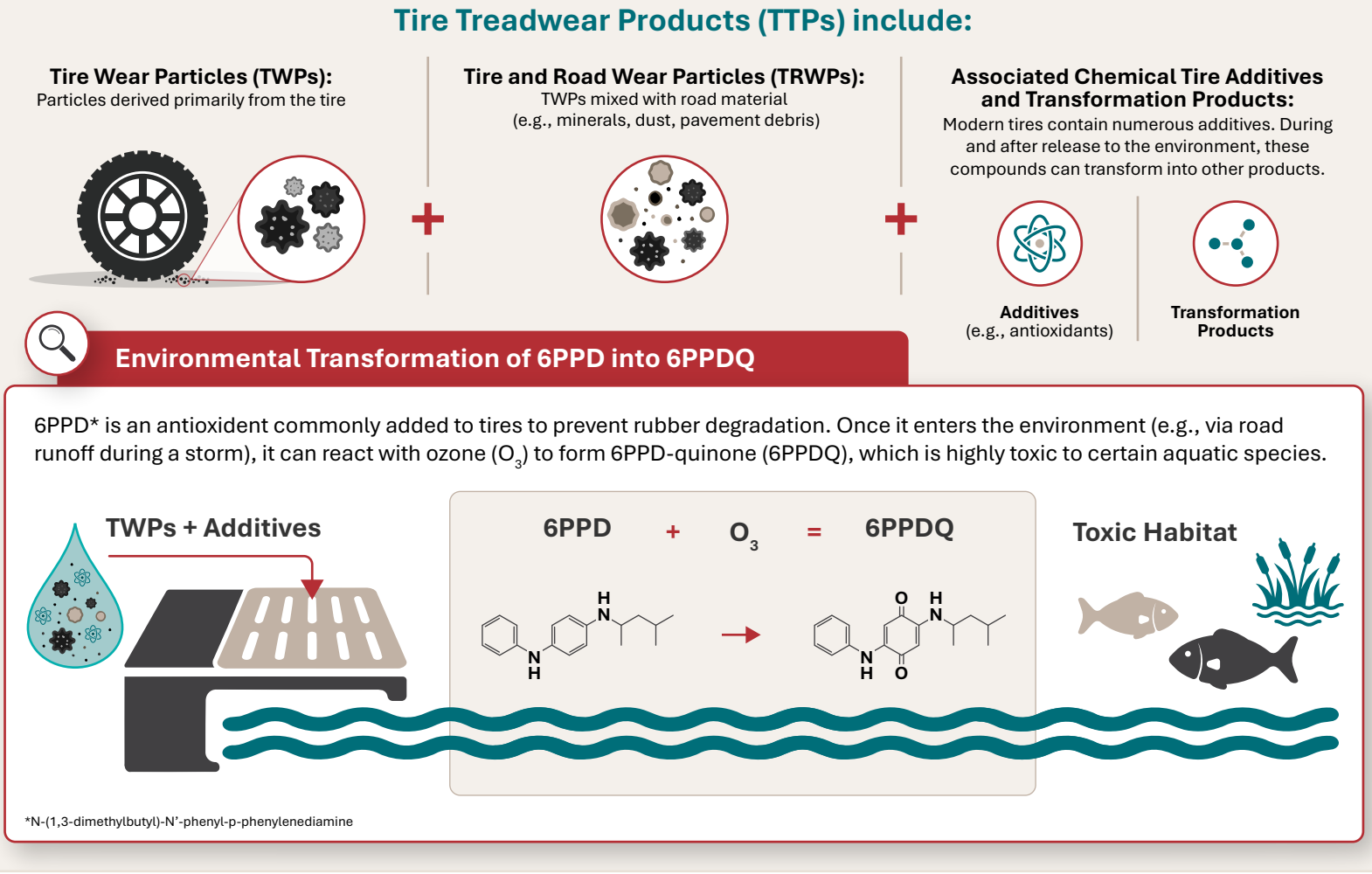


Figure 1. Tire Treadwear Products: A Complex Mixture

6PPDQ: a Contaminant of Emerging Concern

Ecotoxicity

6PPDQ has been characterized by the US Geological Survey as among the most toxic chemicals for aquatic animal life. It was identified as the causative agent in acute coho salmon mortality events—most researched in urban streams in the Pacific Northwest—and toxicity concerns have been identified for other sensitive salmonids, including trout species of ecological and economic importance across the US.

The US Environmental Protection Agency's (EPA) 2024 acute aquatic life screening values are 8,900 ng/L for 6PPD and 11 ng/L for 6PPDQ to protect aquatic life, including sensitive salmonids. Available analytical methods can achieve detection limits ranging from approximately 0.05–5 ng/L, depending on the analytical method and sample volume, enabling evaluation against these screening thresholds. A standardized screening method for the broader range of TTP-associated contaminants has not yet been established.

Human Health

Emerging human biomonitoring studies have detected 6PPD and 6PPDQ in urine, blood, breast milk and other biological matrices, with many studies conducted outside the US, particularly in China. Experimental toxicology studies have identified the potential for liver, reproductive, endocrine and immune effects associated with exposure to these compounds. However, human exposure pathways, health implications, dose-response relationships and toxicity thresholds for 6PPDQ remain uncertain, and additional research is needed to better understand potential risks.

The Extent of the Problem

Although 6PPD has been used in vehicle tires since the 1960s, 6PPDQ was first identified in 2020 by researchers at the University of Washington and Washington State University as a highly toxic stormwater-derived aquatic contaminant in the Pacific Northwest. Since then, 6PPDQ has been detected in urban watersheds across North America, Europe and Asia. Elevated levels are most frequently associated with high-traffic urban areas and storm events.

Concentrations are strongly influenced by:

- Antecedent dry days
- Rainfall intensity and timing
- Urban land use and impervious surfaces
- Proximity to roadways and stormwater conveyance systems

Public health laboratories in urbanized regions and jurisdictions implementing stormwater monitoring requirements may see increasing demand as these contaminants are not typically captured through traditional wastewater or drinking water monitoring programs. While impacts are best documented in the Pacific Northwest, tire-derived runoff is a broader national concern where roadways, stormwater and sensitive aquatic species intersect. 6PPDQ is not currently a routine parameter in Clean Water Act stormwater monitoring programs. Stormwater permits and watershed studies provide a natural sampling framework for emerging contaminants associated with roadway runoff, including TTP-related compounds.

Testing for TPPs

Current Testing Laboratories

Testing services and method development for TPPs are largely concentrated among commercial and government laboratories in the Pacific Northwest, where early implementation has occurred.

Analytical Targets

While public health laboratories consider whether to develop capacity for analysis of TTPs, including 6PPD and 6PPDQ, they may be asked to assist jurisdictional programs in identifying laboratories that can provide analytical services. Current analytical capability is primarily focused on 6PPDQ as a key transformation product of concern due to its established aquatic toxicity. Some laboratories are expanding analysis to include parent compound 6PPD and other tire-derived transformation products and PPD-quinone analogs, which are not yet fully characterized, using multi-analyte mass spectrometry methods (**Figure 2**).

Available Analytical Methods

EPA Draft Method 1634 was published in January 2024 and is currently the primary method for measuring 6PPDQ in stormwater and surface water. It is single-lab validated, performance-based and uses LC-MS/MS. Method performance is strongest in surface water and stormwater matrices, while sediment and other complex matrices may require additional method modification and validation.

Key method features include:

- 250 mL sample volume
- Samples extracted using solid-phase extraction and quantitated using isotope dilution
- Minimum level of quantitation: 2 ng/L

In addition to EPA Draft Method 1634, some laboratories are using laboratory-developed, research, or proprietary analytical methods for 6PPDQ that employ mass spectrometry detection but may differ in sample introduction and extraction approaches (e.g., solid-phase extraction or alternative membrane-based techniques), as well as in internal standards and reporting limits pending broader standardization.

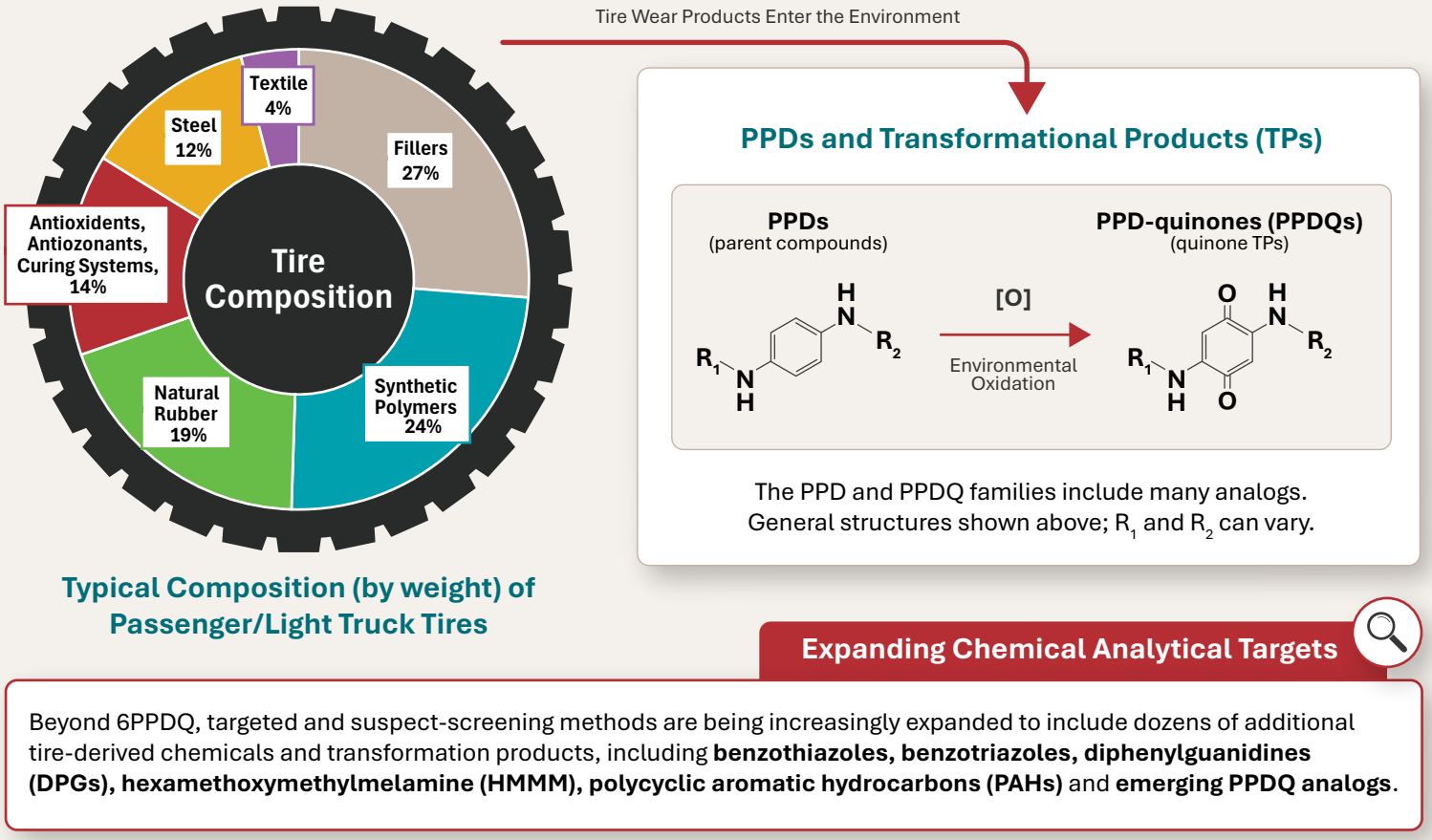
Sampling Challenges

Sample timing is difficult due to 6PPDQ's highly dynamic nature driven by storm events and surrounding hydrology. Unlike routine monitoring programs, 6PPDQ sampling is typically conducted episodically, based upon precipitation events and roadway runoff rather than continuous or chronic collection. Storm-driven variability can result in rapid concentration spikes, and grab sample timing relative to storm onset can significantly influence measured results and complicate data interpretation. These factors underscore the importance of careful site assessments, sampling design and event-based coordination to ensure measurements are representative of concentrations that can be compared to the US EPA draft acute aquatic life screening values.

Recommended field sampling practices include:

- Using amber glass containers with minimal headspace
- Storing at 6°C
- Avoiding chemical preservatives that may alter 6PPD/6PPDQ stability (e.g., sodium thiosulfate or sodium metabisulfite)
- Avoiding plastic containers due to potential losses

Figure 2. Tire Composition and Tire-derived Chemical Expanding Analytical Targets



Looking Forward

Laboratory Considerations

Resource Considerations

When deciding whether to incorporate 6PPDQ testing, public health laboratories should evaluate:

- Availability of LC-MS/MS instrumentation and isotope-labeled standards
- Staff expertise in trace-level environmental organic analysis
- Event-based surge capacity for storm sampling demands
- Future expansion to sediment, tissue, dust or wastewater matrices

Accreditation and Quality Assurance Requirements

Laboratories conducting 6PPDQ analysis generally operate under ISO/IEC 17025 accreditation or equivalent state environmental laboratory accreditation programs, with method validation required to demonstrate suitability for low-level detection in stormwater and surface water matrices.

These considerations reflect the specialized analytical capability required for ultra-trace detection in complex environmental matrices and may present implementation challenges for laboratories without existing LC-MS/MS environmental organic contaminant programs.

Key Data Gaps Relevant to Laboratories

Analytical Gaps

- Inter-laboratory performance data for current water methods
- Standardized methods for non-water matrices

Toxicological Gaps

- Human health thresholds
- Chronic aquatic life criteria

Exposure Gaps

- US population biomonitoring data
- Relative contribution of water, dust and air pathways
- Physiochemical properties for modeling of environmental fate, distribution and exposure

Research Focus Areas

A growing number of tire-derived transformation products and related compounds have been identified through targeted and non-targeted analytical studies, though toxicological and environmental data remain limited for most compounds beyond 6PPDQ. Current research priorities in the US include:

- **Fate and transport in sediments**
- **Treatment technologies (e.g., biochar, green infrastructure)**
- **High-frequency and passive sampling methods**
- **Human biomonitoring method development (CDC currently developing)**
- **Additional PPD-quinone analogs (e.g., DTPD-Q and DPPD-Q)**
- **Broader TRWP/TTP-associated contaminants (e.g., benzothiazoles, phthalates and other tire-derived chemicals and transformation products)**

Conclusion

TTPs, including 6PPDQ, are an emerging class of roadway-related contaminants detected in stormwater-impacted aquatic systems. 6PPDQ is an established aquatic toxicant affecting sensitive species, particularly salmonids, while broader ecological impacts and potential human health implications of TTP exposure remain uncertain. Public health laboratories should assess analytical capacity, anticipated demand and alignment with emerging contaminant surveillance priorities prior to adoption. Early coordination with environmental partners and engagement in sampling and method development and validation efforts can support consistent implementation as approaches continue to evolve.

Resources

- **6PPD Discovery:** Tian Z, Zhao H, Peter KT, et al. A ubiquitous tire rubber–derived chemical induces acute mortality in coho salmon. Science. 2021;371(6525):185–189. DOI:10.1126/science.abd6951
- **6PPD/6PPDQ Guidance:** Interstate Technology & Regulatory Council. 6PPD & 6PPD-quinone Guidance. 2024. 6ppd.itrcweb.org
- **Key Review on Tire-related Chemicals:** Paul Mayer, Jen McIntyre, Ed Kolodziej, et al. Where the rubber meets the road: Emerging environmental impacts of tire wear particles and their chemical cocktails. Science of The Total Environment. 2024;927. DOI: 10.1016/j.scitotenv.2024.171153.
- **Acute Aquatic Life Screening Value:** US Environmental Protection Agency (EPA). Acute Aquatic Life Screening Value for 6PPD-quinone in Freshwater. EPA 822-R-24-004. Published May 2024. www.epa.gov/system/files/documents/2024-05/6ppd-q-screening-value-2024.pdf
- **US EPA DRAFT Method 1634:** US Environmental Protection Agency. 6PPD-q Using Liquid Chromatography with Tandem Mass Spectroscopy (LC/MS/MS)—Draft Method 1634. EPA 821-D-24-001. Published January 24, 2024. www.epa.gov/system/files/documents/2025-02/draft-method-1634_1-24-24_508.pdf.
- **US Geological Survey Research on 6PPDQ:** www.usgs.gov/programs/environmental-health-program/science/usgs-research-6ppd-quinone-where-rubber-meets-road
- **APHL 6PPDQ and Tire Treadwear Chemicals Webinar Series:**
  - PART 1 Emerging Contaminants in Tire Treadwear: Exposure Pathways, Health Effects, and the 6PPD-Quinone Discovery
  - PART 2 Detecting 6PPD-Quinone: Sampling Challenges and Analytical Approaches

Association of Public Health Laboratories

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This project was 100% funded with federal funds from Cooperative Agreement #20NU60OE000104C6 from the US Centers for Disease Control and Prevention (CDC). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of CDC.